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Color Television

By the Engineering Department, Aerovox Corporation

Although the adoption of a system of color television for regular commercial telecasting has been long delayed by hearings, court battles and injunctions, there is nothing in these legalistic proceedings to prevent the experimenter, technician and radio engineer from preparing himself technically for the eventual debut of this service. No one who has witnessed the pleasing brilliance of a television program in full color can doubt that the adoption of this form of TV broadcasting as a standard is inevitable. Neither can anyone doubt that the burden (and profit) of converting many of the millions of black-and-white receivers to color reception will fall on the shoulders of the able TV technician.

So, while industry battles bitterly over ways and means, this issue of the AEROVOX RESEARCH WORKER is devoted to an unbiased and non-political discussion of the fundamental principals of color television which apply equally to all of the systems as yet proposed. A description of the three systems which have been demonstrated before the F. C. C. is also included.

Color Fundamentals

All systems which have been considered for color TV in this country are trichromatic in nature, i.e., three primary colors are used in various combinations to form all the hues of the visable spectrum. The primary colors employed are not the familiar red-blue-yellow used in art and color printing, but rather a more basic red-green-blue combination. These primaries are know as the "additive" primaries whereas the red-blue-yellow primaries (more accurately "magenta-cyan and lemon-yellow" since they are complex colors made up of bluish red, bluish green and greenish yellow, respectively) are known as the "subtractive" primaries. The distinction comes from the fact that a subtractive color filter *subtracts* one color from pure white light passing through it, leaving a complex hue made up of all other colors, while an additive filter absorbs all colors in the spectrum but one. In this respect the subtractive color filter is analogous to an electrical *band-rejection* filter, while an additive color filter is like an electrical *band-pass* filter. This concept is illustrated in Fig 1, which shows the response of an additive color filter as a solid line and that of a subtractive filter as a dotted line.

In all practical systems of color television, the additive primary colors are transmitted one at a time. How-

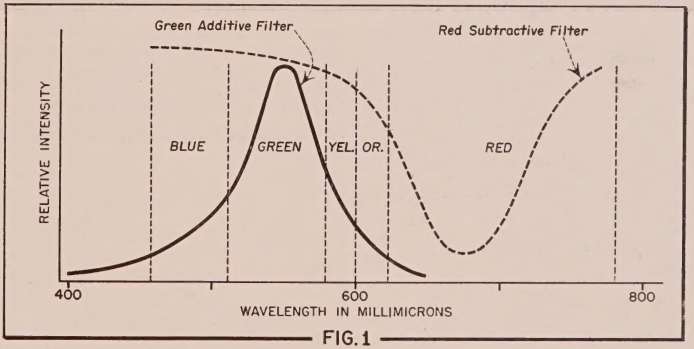

FIG. 1

CORRECTION

Despite careful fact findings, writing and editing, two errors crept into the January 1951 issue, describing a TV Field Strength Meter.

Referring to a silicon crystal mixer (page 2, second column), the engineer-writer states that same is readily available on the surplus market. Again, with further reference to the crystal mixer (page 3, first column), he states that same and other detector crystals are available from surplus stock.

Inasmuch as the engineer-writer who prepared the article was interested solely in providing practical data, he was unaware of company policy. His statements, therefore, do not reflect any change in Aerovox policy which remains unalterably opposed to the promotion of surplus merchandise.

Since crystal diodes are available as new items from prime sources, there is no reason why the builder of the TV Field Strength Meter should take a chance on surplus components.

Charles Golenpaul
Sales Mgr. Dist. Div.

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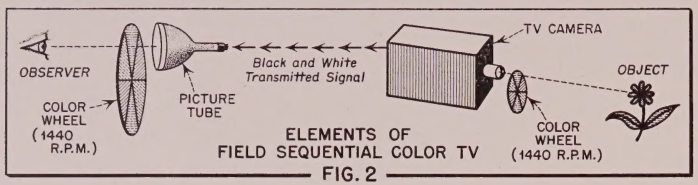


ELEMENTS OF
FIELD SEQUENTIAL COLOR TV

FIG. 2

ever, if two or three of the primary colors are transmitted in a time interval which is shorter than the persistance of vision of the human eye (about 1/16th of a second) the eye sees the "secondary" color formed by those primaries. Thus, a yellow object is produced by transmitting its image in both red and green, in rapid succession. The various tones or shades of yellow are formed by varying the relative intensities of the two primaries forming it. In the same manner all other colors are produced by transmitting their primary color values in *sequence*. This method, which is common to all systems practical for broadcast use, is therefore called the "sequential" system of color transmission. The various systems using it differ essentially only in regard to the rapidity with which the color values of the composite color picture are sequentially "sampled.

The Field Sequential System

The elements of a *field sequential* system, which is the simplest in all respects, are shown in Fig. 2. In this system, the colors are switched after the transmission of each field. A rotating color wheel placed in front of the camera tube causes the scene being televised to be passed through a different additive primary color filter during the scanning of each field. Thus, one field contains information on only the red elements of the picture, the next field only the blue and the next field green. Field interlacing is used and six fields are required to produce a complete color picture. At the standard black-and-white field frequency of 60 per second, a six field picture would be produced only each 1/10th second — not fast enough to avoid "flicker" on scenes which are predominantly of one color. Therefore, field sequential transmission of color requires 144 fields per second. This gives 24 complete pictures per second, which is safely above the "flicker" rate.

At the receiving end, the field sequential system employs a process which is the reverse of that used for transmission. The picture tube is viewed through a rotating color wheel which is synchronized with the one at the transmitter in both speed (1440 rpm.) and phase. A filter of the same color is thus before both the camera pick-up tube and the receiver cathode ray tube at any given time. Suppose the color is green. The camera tube then "sees" only the green elements of the picture and these are transmitted in the usual manner to the receiver which reproduces them as white light. The additive filter between the viewer and the picture tube passes only the green light, however, so that the green highlights of the picture are faithfully reproduced. The green field is rapidly followed by one in red, one in blue, etc. The intermediate colors in the picture are then formed by the superposition of the primary fields on the retina of the eye.

The advantages of the field sequential system of color TV are mainly the economy and simplicity of the equipment required. For the expenditure of only a few dollars, many experimenters have converted standard receivers to satisfactorily receive test transmissions in color using this system. Other advantages include excellent color fidelity.

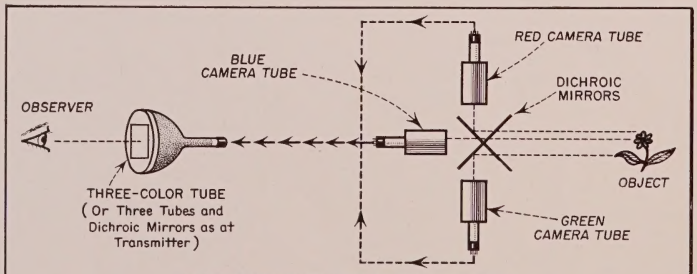
The major disadvantage of the system is that it is not "compatible". This means that a program transmitted in color by the field sequential method cannot be received in black-and-white on standard receivers without modification. Since the color transmissions use a horizontal line frequency of 29,160 instead of the standard 15,750 lines per second, and a vertical sweep frequency of 144 per second rather than the present 60 per second, sweep circuit changes must be made in the existing sets to permit reception in either black-and-white or color. This is termed "conversion" and ranges in complexity from very minor changes in some sets to major redesigns in others. The task of performing such conversions would probably fall to the TV service technician who is qualified for such work.

Another disadvantage of the field sequential system, as it is presently being demonstrated, is the bulkiness of the mechanical color disc. Since each of the six color filter segments arranged on this wheel must be large enough to cover most of the picture tube face, the wheel must be at least twice the diameter of the tube. This sets a practical limit on the size of the picture tube which can be used — tubes larger than about 12½ inches requiring discs of ungainly proportions. However, magnification can easily be employed to provide larger pictures from small tubes. Other forms of the color wheel, such as the color cone or color drum shown in Fig. 3, have form factors more adaptable to TV cabinets. No problem exists at the transmitter, since the filters used need only be large enough to cover the camera lens.

The field sequential system is not essentially "mechanical". The color wheel could readily be replaced with an all electronic, three-color picture tube if a practical one were commercially available.

Line Sequential Color Television

Another method of color transmission which has been demonstrated is called *line sequential*. As the name implies, colors are switched sequentially after each line rather than after each field. Therefore, color switching occurs 15,750 times per second instead of 144 times as in the field sequential system. Each of the standard 60 fields per second is made up of alternately red, green and blue lines. Line interlace is used and six fields must be sent before each of the 525 lines is scanned in each color. This results in only 10 complete "frames", or pictures, per second.



SIMPLIFIED DOT SEQUENTIAL SYSTEM

FIG. 5

However, flicker is minimized to a large extent by the line interlacing.

Fig. 4 shows the elements of the line sequential system. At the pick-up end, an optical mixing arrangement consisting of three lenses and three color filters focusses the scene being televised on the camera tube mosiac so that the three color images appear side by side. The electron beam sweeps across all of the pictures in succession to generate sequentially colored lines.

Here again the transmission process is reversed in receiving colored pictures by the line sequential system. Three images containing the separate color information are reproduced side-by-side on the picture tube face. These images are viewed through separately colored filters and an optical system which superimposes them so that they appear to the observer as one colored image.

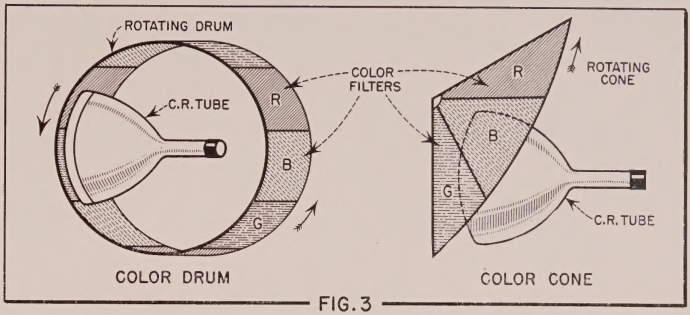


FIG. 3

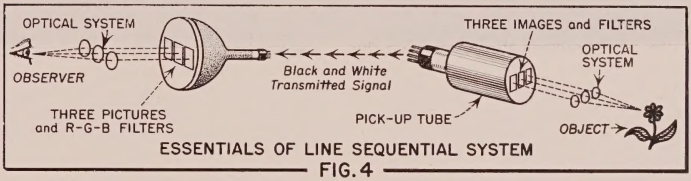


FIG. 4

Since the line sequential system conforms to present TV standards it is compatible and could be received equally well on either black-and-white or color receivers. Its major disadvantage is an effect called "line creep" or "line crawl" which is particularly distracting to the eye since prominent color lines seem to be moving up or down through the picture.

The Dot Sequential System

The dot sequential method of color transmission goes one step farther than the line sequential approach and breaks each line up into many picture elements or "dots" which are transmitted sequentially in the three primary colors. To do this, color switching must be accomplished almost 11 million times per second. This high sampling rate is responsible for both the good features and some of the bad features of this method, as will be mentioned later.

To transmit dot sequential television, three separate pick-up tubes are used. The televised scene falls on the three mosiacs through a system of *dichroic mirrors*, as in Fig. 5. Each mirror is transparent to two primary colors but reflects the third. Thus each tube receives picture information in one color only. An electronic sampling system connects the transmitter sequentially to the output of the three camera tubes at the rate of 3.6 *million* cycles per second. Each line consists of about 420 dots in alternate colors. Four fields are used per frame — two fields of standard line interlace and two of "dot interlace" wherein dot elements of the third and fourth fields fall midway between dots of the first and second fields, respectfully. By this means, all elements of the picture are scanned in each color 15 times per second.

As in the previously described systems, this method reverses the transmitting procedure for receiving. One way of achieving this is to use three picture tubes, each viewed through a separate color filter and superimposed with a dichroic mirror. The color dot information is then electronically switched to the proper color tube for reproduction. The color sampling circuit at the receiver is synchronized with that at the transmitter.

Since the use of three cathode ray tubes or color reproduction is both costly and cumbersome, much effort is being expended on the development of a single tube capable of three-color reproduction. Such a tube has been successfully demonstrated, but has not been commercially perfected. Fig. 6 illustrates the principle of its operation. The screen is made up of 600,000 dots of colored phosphors, 200,000 each of red, green and blue. A perforated metal screen is arranged between the phosphors and three separate electron guns in such a manner that each gun excites dots of only one color.

The advantages of the dot sequential system are compatibility and high definition. Its disadvantages are complexity, higher cost for conversion, and the fact that the high sampling rate of 3.6 megacycles per second prevents its use with some existing cable facilities.

In accordance with its editorial policy of keeping its readers abreast of current developments of interest, future issues of the AEROVOX RESEARCH WORKER will contain further information on this subject.

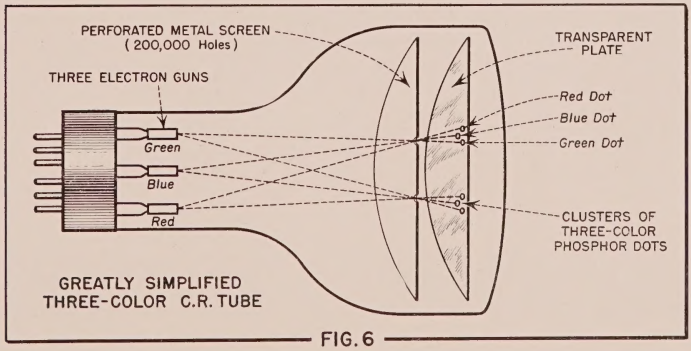


FIG. 6

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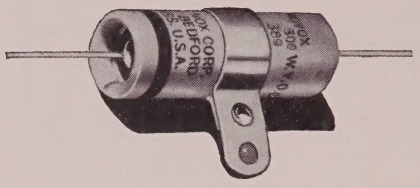

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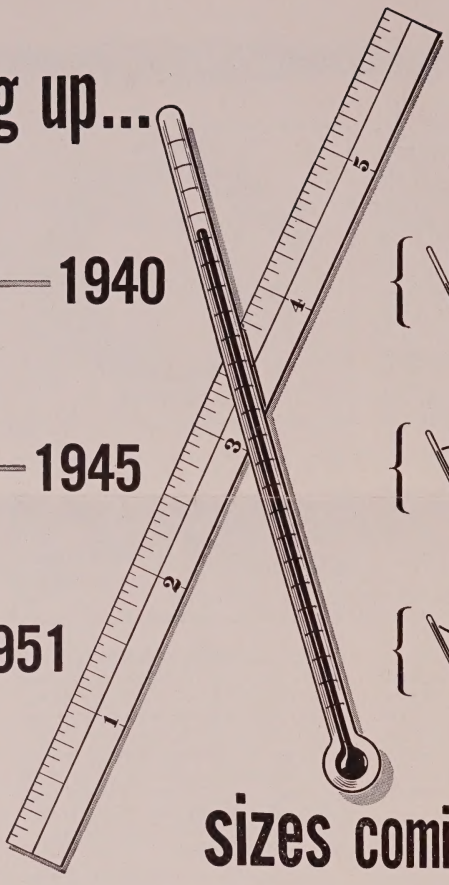

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